CARBON DIOXIDE (CO_2) LASER CUT QUALITY OF ACRYLIC WITH DIFFERENT POWER LEVELS

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I declared that this dissertation entitled "Carbon Dioxide (CO_2) Laser Cut Quality of Acrylic with Different Power Levels" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not currently submitted in candidature of any other degree.

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DEDICATION

To my beloved father and mother

Mr. Abdullah Bin Yaacob
Mdm. Wan Zainab Binti Wan Jaffar

To my supervisor

Mdm. Nurul Shahida Binti Mohd Shalahim

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this project. I am deeply indebted to my supervisor Puan Nurul Shahida binti Mohd Shalahim from the Faculty of Mechanical Engineering (FKM) whose help, stimulating suggestions and encouragement helped me in all the time of doing this project. I also would like to express my deep and sincere gratitude to my co-superviser Mr. Mahendran Samykano, for his detailed and constructive comments, and for his crucial support throughout this project. My overstate gratitude to Associate Professor Dr Wan Azhar bin Wan Yusoff and En Nafrizuan bin Mat Yahya, for their enthusiasm, inspiration, and great efforts to explain things clearly. Not forgetting a master student, Mr. Khairul Fikri Bin Muhammad for willing to spend his valuable time, assisting me throughout this work.

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My debts to my respective families for their assistance, love, encouragement, and patience, as always, exceed my gratitude.

ABSTRACT

Laser is widely applied in today's industry. Laser is widely used in industry for cutting and boring metals and other materials, in medicine for surgery, and in communications, scientific research, and holography. Laser cutting machine is often used in marking or engraving wood, glass, acrylic, rubber, ceramics, coated metals and marble. Laser cutting machine has greater advantages compared to the traditional method for cutting the material. It produces better cut quality of material. The project is to examine the effects of laser cutting of acrylic material with the use of different power levels and constant feed rate. The effects on both parameters, which are striation frequency and the size of HAZ, are analyzed. Manual analysis was used to develop graphs that describe the effects of power on laser cut quality. The suitable desired power level to get the optimum cut quality of acrylic is 22.5 watts at feed rate 1800 μs. For optimum cut quality, striation frequency and size of HAZ parameters are kept at minimum levels. Increasing power leads to the decrease of striation frequency. The size of HAZ increases when there is an increase in power. Power laser produces small effects on the striation frequency and size of HAZ. Study and analyze the other parameters or factors that affect the cut quality of acrylic should be consider for the future research.

ABSTRAK

Hari ini, laser diterapkan secara meluas dalam industri. Laser digunakan secara luas di industri untuk memotong dan membuat lubang pada logam/besi dan bahan lain, dlm bidang perubatan, komunikasi, kajian saintifik, dan holografi. Mesin laser pemotong sering digunakan dalam penandaan atau pengukiran kayu, kaca, acrylic, getah, seramik, lapis metal dan marmar. Mesin laser pemotong mempunyai banyak kelebihan berbanding dengan cara tradisional dalam pemotongan bahan. Mesin laser pemotong boleh menghasilkan kesan pemotongan yang baik terhadap bahan yang dipotong. Projek ini bertujuan untuk mengkaji kesan pemotongan laser terhadap bahan iaitu, acrylic dengan menggunakan kuasa laser yang berlainan serta kadar pemotongan yang tetap. Kesan terhadap kedua-dua parameter iaitu frekuensi pengoresan dan saiz zon kesan pemanasan dianalisis. Analisis manual digunakan untuk membuat graf yang menunjukkan kesan kuasa ke atas kualiti pemotongan laser. Tahap kuasa laser yang sesuai digunakan untuk mendapatkan kualiti pemotongan yang optimum adalah 22.5 watts pada kadar potongan 1800 μs. Untuk mendapat kualiti pemotongan yang optimum, parameter frekuensi pengoresan dan zon kesan pemanasan ditetapkan pada tahap minimum. Peningkatan pada kuasa menjurus kepada penurunan frekuensi pengoresan. Saiz zon kesan pemanasan meningkat apabila kuasa ditambah. Kuasa laser menghasilkan kesan yang kecil pada frekuensi pengoresan dan zon kesan pemanasan dianalisis. Kajian dan analisis parameter atau faktor lain yang mempengaruhi kualiti pemotongan acrylic perlu diambil kira untuk kajian masa akan datang.

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mm	-	Millimetre
W	-	Watt
μ	-	Micron, 1 x 10_{-6}
cm	-	Centimetre
m	-	Metre
lb	-	pound
in	-	inch
°F	-	Degree Fahrenheit
hr	-	hour
ft	-	Feet
s, sec	-	Second
Hz	-	Hertz

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Laser, which stands for Light Amplification by Stimulated Emission of Radiation, is an electrical-optical device that produces coherent radiation. Simply put, a laser is a device that creates and amplifies a narrow, intense beam of coherent light. Nowadays, laser is widely applied in today's industry.

Lasers are widely used in industry for cutting and boring metals and other materials, in medicine for surgery, and in communications, scientific research, and holography. They are an integral part of such familiar devices as bar code scanners used in supermarkets, scanners, laser printers, and compact disk players. One of the laser systems that dominate the commercial laser industry is CO_2 laser systems. It has its own strengths in various cutting and marking applications.

The concept used in developing the laser-cutting machine is the concept of stimulated emission which was first suggested by Albert Einstein in 1916 by proving the Planck's Law of Radiation. Laser cutter machine is being used for an increasing number of applications in sheet metal processing and represents a unique quality. The high level of production flexibility and the almost unlimited diversity of materials and shapes explain its worldwide recognition as an indispensable basic technology. High precision of the dimensions and minimum heat distortion of the sheet parts are just two of the

advantages that convince the user of the first class cutting results.Laser cutting machine is often used in marking or engraving wood, glass, acrylic, rubber, ceramics, coated metals and marble. In the higher wattage (25 or greater), material such as acrylic may be completely and accurately cut out to form various shapes.

Acrylic is a versatile material and has been used in a wide range of fields and applications. It is a useful, clear plastic that resembles glass, but has properties that make it superior to glass in many ways. Acrylic also is completely transparent, rigid, and exhibits great resistance to breakage. As for these characteristics, acrylic has become widely used in today's industry. It is used to make various products, such as shower doors, bath enclosures, windows and skylights. It is chosen over glass for many reasons. It is many times stronger than glass, making it much more impact resistant and therefore safer. Falling against an acrylic shower door will not likely break it. Baseballs that crash through glass windows will, in most cases, bounce off acrylic windows. Acrylic also insulates better than glass, potentially saving on heating bills. Another great advantage of acrylic is that it is only half as heavy as glass. This makes working with acrylic much easier. It can also be sawed, whereas glass must be scored. [12]

In the present days, the applications include inspection windows, sight gauges, windshields, meter faces, protective covers, safety shields, tanks, desk tops, displays, trays, and chair pads. Acrylic comes in a wide variety of standard colors (colorless sheet). It is seen in malls, institutions, prisons, hospitals and commercial buildings. The fact that some of them are bullet resistant, it is now in highly demand.

Acrylics come in various shapes. There are many ways of processing them, and the one discussed here is the process done by using laser cutter machines. The process is called laser cutting process. Some parameters need to be made emphasis to determine the laser cut quality. This research is done to evaluate crucial aspects of the laser cutting process.

1.2 PROBLEM STATEMENT

This experiment is conducted to analyze the parameters while cutting the acrylic using different powers of laser cutting machine. So, investigate what happens to that material when we cut it using different powers. In this project, the most important variables to be controlled are the power and feed rate. The difficult part of this project is to set the power of the laser cutting machine.

The experiment is conducted to analyze the effects of power values on cut quality of materials, which are striation frequency and HAZ. The most suitable power value to produce optimum cut quality is still unknown (power value which produces high quality on both parameters).

1.3 OBJECTIVES

The objectives of this study are:

1.3.1 To study and analyze the effects of different power values with a constant feed rate value in laser cut quality of acrylic.

1.3.2 To find the suitable power to get the optimum cut quality on striation frequency and the size of heat-affected zone (HAZ).

1.4 PROJECT SCOPES

The scopes of the study are:

1.4.1 Experiment and analyze the laser cutting quality by using the material of acrylic.

1.4.2 Study the laser cut quality parameter such as striation frequency and HAZ.

1.4.3 Run the experiment using different power values.

1.4.4 Analyze the data by using manual analysis.

1.5 THESIS ORGANIZATION

This thesis is divided into five chapters and each chapter has its own sub-topics. The first chapter, the introduction explains the preface of acrylics and laser cutter machines. The preface includes the characteristics and also the applications of both materials in today's industry. Advantages of both materials are included as well. The objectives are to explain the importance of carrying out the research. As for the problem statements, all problems and limitations faced during the research are pointed out. Scopes of the project are noted in this chapter as well.

In Chapter 2, definitions of terms associated with the research are stated. The terms are acrylic, surface roughness, striation frequency, and heat-affected zone. The definitions are entailed with the application in today's industry. There is also inclusive explanation on basic components of lasers and how they work.

Chapter 3 presents the methodology of the research. Methods or any particular procedures used to complete the experiment are noted in this chapter. It also includes the chronology of the research.

Results of the conducted experiment are stated in chapter 4. The results are gathered and discussed. Elaboration regarding the experiment is provided as well.

This is the final chapter. General indication of the project is explained in this chapter. Suggestions of reducing the effects or problems when cutting the acrylic are pointed out. The optimum power of giving the good cutting quality of acrylic is mentioned as well. Recommendation regarding the project is pointed out for the benefits in future tasks.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review is a critical look at the existing research that is significant to the project. In the literature review, evaluation what has already been done. It is also to show how it is related to the current project. The literature review refers to any collections of materials on a topic. It is not supposed to be just a summary of other people's work.

This chapter will discuss on the working principles, basic components of laser, definitions of term associated with the research and parameters of cut quality.

2.2 LASER

2.2.1 History and Development

The process which makes lasers possible, Stimulated Emission, was proposed in 1917 by Albert Einstein. No one realized the incredible potential of this concept until the 1950's, when practical research was first performed on applying the theory of stimulated emission to making lasers. It wasn't until 1960 that the first true laser was made by Theodore Maimam, out of synthetic ruby. Many ideas for laser applications quickly followed, including some that never worked, like the laser eraser. Still, the early pioneers of laser technology would be shocked and amazed to see the multitude of ways that lasers are used by everyone, everyday, in today's world. [9, 20]

Since the early period of laser history, laser research has produced a variety of improved and specialized laser types, optimized for different performance goals, including new wavelength bands, maximum average output power, maximum peak output power, minimum output pulse duration, maximum power efficiency, maximum charging and maximum firing, and this research continues to this day. [14]

2.2.2 Components of a Laser

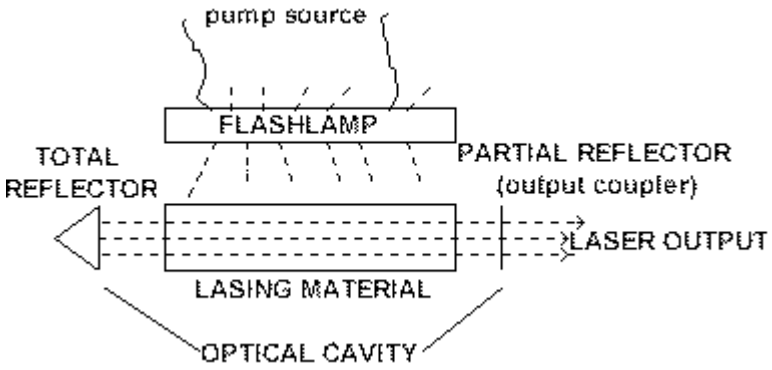


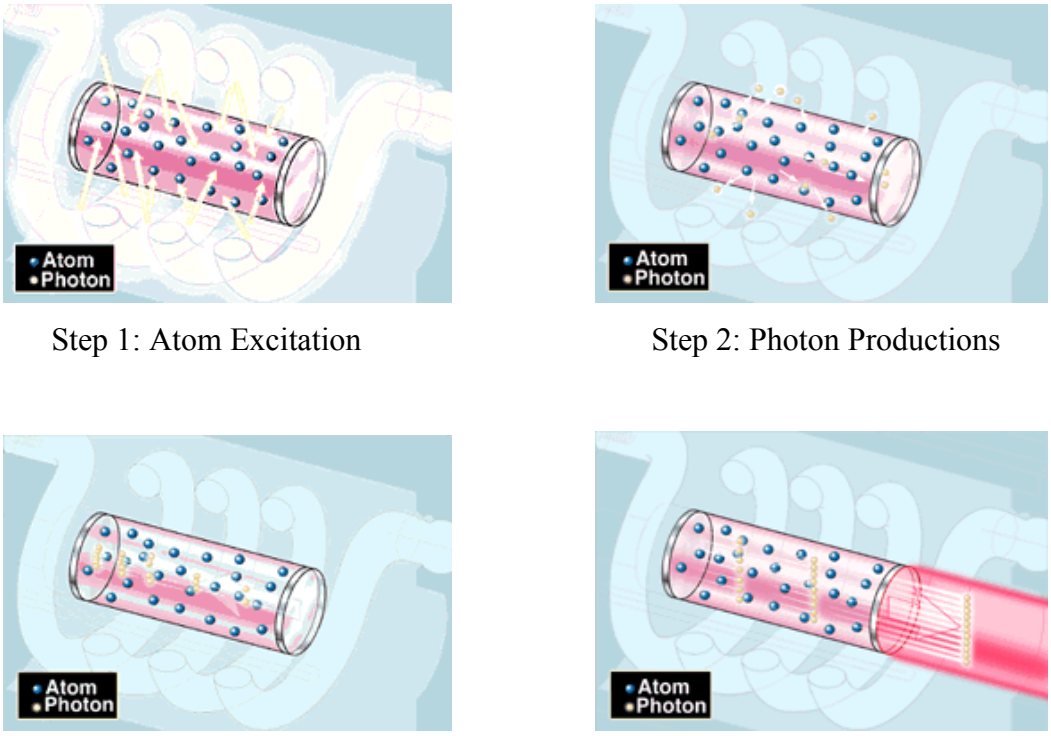
Figure 2.1: Solid State Laser Diagram

Source: Mary Bellis [17]

Figure 2.2 illustrates the basic components of the laser. The components are lasing material, pump source or excitation medium, optical cavity and output coupler. The lasing material can be a solid, liquid, gas or semiconductor, and can emit light in all directions. The pump source is typically electricity from a power supply, lamp or flashtube, but may also be another laser.

The excitation medium is used to excite the lasing material, causing it to emit light. The optical cavity contains mirrors at each end that reflect this light and cause it to bounce between the mirrors. As a result, the energy from the excitation medium is amplified in the form of light. Some of the light passes through the output coupler, usually a semi-transparent mirror at one end of the cavity. The resulting beam is then ready to use for any of hundreds of applications. [14]

2.2.3 Working Principle of Laser



Step 1: Atom Excitation

Step 2: Photon Productions

Step 3: Reflection

Step 4: Laser Beam Prodction

Figure 2.2: Laser Working Principles

These are the process of generating laser beam. In the first picture, it is illustrated that high-voltage electricity causes the quartz flash tube to emit an intense burst of light, exciting some of the atoms in the ruby crystal to higher energy levels. It is stated in picture 2 that at a specific energy level, some atoms emit particles of light called photons. At first the photons are emitted in all directions. Photons from one atom stimulate emission of photons from other atoms and the light intensity is rapidly amplified. Picture 3 explains that mirrors at each end reflect the photons back and forth, continuing this process of stimulated emission and amplification. And the last process is the photons leave through the partially silvered mirror at one end. This is laser light. [7, 18]

2.3 CO_2 LASER CUTTING MACHINE

Laser cutting is a technology that uses a laser to cut materials and is usually used in industrial manufacturing. Laser cutting works by directing the output of a high power laser, by computer, at the material to be cut. The material then melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials. Some 6-axis lasers can perform cutting operations on parts that have been pre-formed by casting or machining.

Laser cutting usually works much like a milling machine would for working a sheet in that the laser (equivalent to the mill) enters through the side of the sheet and cuts it through the axis of the beam. In order to be able to start cutting from somewhere else than the edge, a pierce is done before every cut. Laser cutting machine allows you to create intricate designs and highly detailed inlays with a low-cost, highly profitable tool. Attached to the computer just like a printer, the system will cut designs we create in most graphic software programs. Set up the page size to the size of the piece we are engraving, create our image, and print it to the laser.

The carbon dioxide laser (CO_2 laser) was one of the earliest gas lasers to be developed (invented by Kumar Patel of Bell Labs in 1964) and is still one of the most useful materials ever created. Carbon dioxide lasers are the highest-power continuous wave lasers that are currently available. They are also quite efficient: the ratio of output power to pump power can be as large as 20%. This machine can cut through wood, acrylic, plastic, cloth, leather, matte board, melamine, paper, pressboard, rubber, wood veneer, fiberglass, cork and many other materials. The advantages of CO_2 laser cutting machine are: [9, 20]

i. The laser creates a beam of light that is used to cut through the material, so there is no part of the laser system in contact with the material.

ii. For thinner materials, all Epilog laser systems include an Integrated Vacuum Table to hold down papers, fabrics, and thin plastics as you cut through the material.

iii. It is amazingly precise, following the pattern you've drawn on screen.

iv. Cut several patterns from the same piece of material.

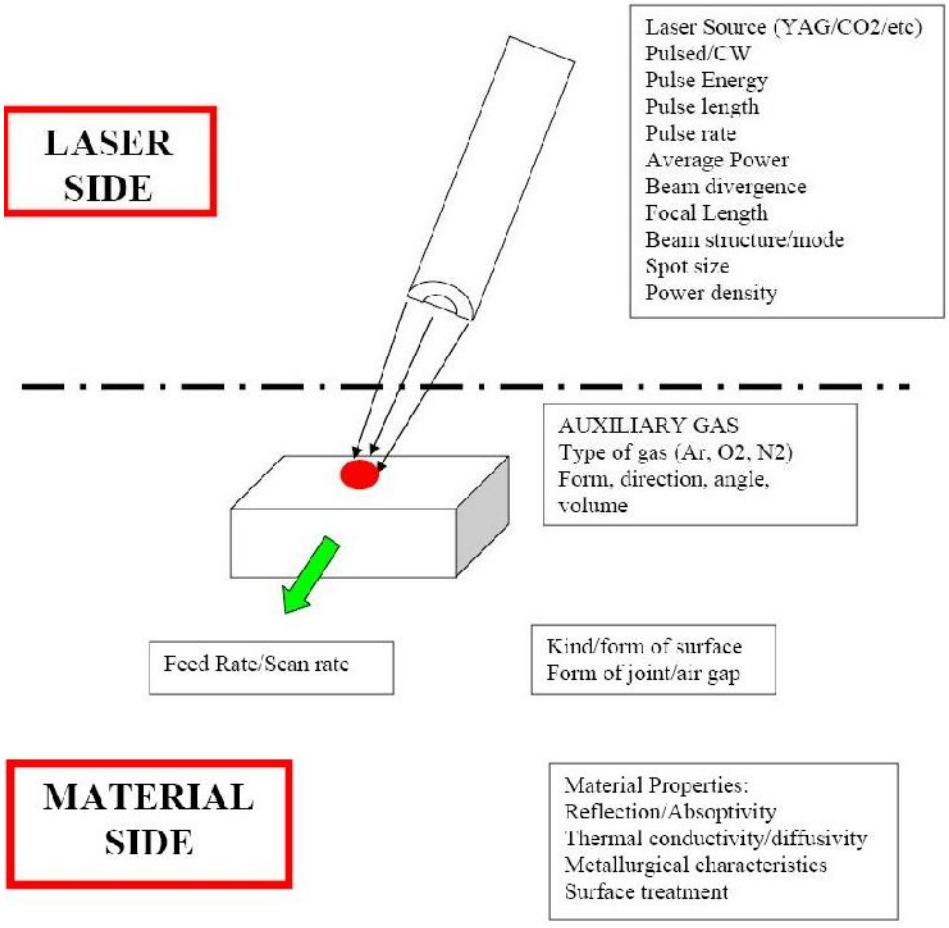


Figure 2.3: Laser Precision Process: Important parameters, which influence material processing

2.4 ACRYLIC

Acrylic is widely known for its importance to the industry. It is used to make various products, such as shower doors, bath enclosures, windows and skylights. It is chosen over glass for many reasons. It is many times stronger than glass, making it much more impact resistant and therefore safer. Falling against an acrylic shower door will not likely break it. Acrylic also insulates better than glass, potentially saving on heating bills. Another great advantage of acrylic is that it is only half as heavy as glass. This makes working with acrylic much easier. It can also be sawed, whereas glass must be scored. [12]

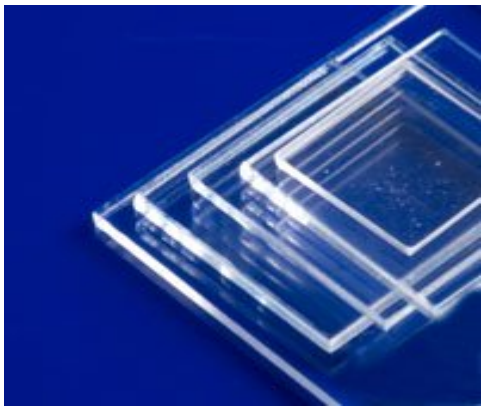


Figure 2.4: Acrylic

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